

Appendix B

Performance Tests for General Radiographic Units Fixed and Portable

A. General Requirements for Radiographic Equipment

1. *Radiation Exposure Reproducibility*

a. Purpose: To ensure that exposure received for the same mA, time, and kVp is the same from exposure to exposure.

b. Regulations: Determination of reproducibility shall be based on 10 consecutive measurements within a time period of one hour, using the same technique factors. For any specific combination of selected technique factors, the estimated coefficient of variation of radiation exposure shall be no greater than 0.05. (21CFR Ch 1 1020.31 (b)(1))

The coefficient of variation is the ratio of the standard deviation to the mean value of a population of observations. (21 CFR Ch 1 1020.30 (b)(3))

$$C = \frac{s}{\bar{X}} = \frac{1}{\bar{X}} \left[\sum_{i=1}^n \frac{(X_i - \bar{X})^2}{n-1} \right]^{1/2}$$

s = Estimated standard deviation of the population

X = Mean value of observations in sample.

X_i = ith observation sampled.

n = Number of observations sampled.

c. Equipment: Electrometer with small ion chamber.

d. Procedure: Set the x-ray tube at 40 inches source-to-table distance, if possible. Place the center of the ion chamber 4 inches above the x-ray table top and center the chamber in the light field. Determine the distance from the focal spot to the center of the ion chamber. Collimate the

light field to a narrow beam geometry (e.g. 4x4 cm field) to include the ion chamber. Make radiation exposures at the selected technique. For efficiency, the evaluator is reminded that some meters will read out both exposure and time, therefore, record both for future measurements.

e. Interpretation of results: If the coefficients of variation deviate from the criteria in [Table 2.1](#) consult a qualified service engineer. Exposure reproducibility is critical as it directly influences image quality and patient dose.

2. *Timer Reproducibility*

a. Purpose: To ensure that the x-ray generator is producing exposure times that are the same from exposure to exposure.

b. Regulations: Determination of reproducibility shall be based on 10 consecutive measurements within a time period of one hour, using the same technique factors. For any specific combination of selected technique factors, the estimated coefficient of variation of radiation exposure shall be no greater than 0.05.

c. Equipment: Exposure timer or exposure meter with timer combination.

d. Procedure: Utilize the procedure described for reproducibility measurements. Measure and record the actual exposure time for 10 exposures at the same timer setting (e.g. 100 msec).

e. Interpretation of results: If the coefficients of variation deviate from the criteria in [Table 2.1](#) consult a qualified service engineer. Timer reproducibility is critical as it directly influences image quality and patient dose.

3. *Timer Accuracy*

- a. Purpose: To ensure that the x-ray generator is producing the exposure time as set on the control panel.
- b. Regulations: The accuracy of the timer should be within $\pm 5\%$ of the selected timer setting or ± 1 ms for exposure times less than 10ms or 1 pulse for exposure times less than 10 pulses.
- c. Equipment: Exposure timer or exposure meter with timer combination.
- d. Procedure: Utilize the procedure described for reproducibility measurements. Measure and record the full range of clinically useful exposure times.
- e. Interpretation of results: Refer units deviating from the criteria in [Table 2.1](#) for adjustment by a qualified service engineer. Timer accuracy is critical as it directly influences image quality and patient dose.

4. *Linearity of mA/mAs*

- a. Purpose: To ensure that similar exposures are obtained for the same mAs and kVp regardless of the exposure time and mA used.
- b. Regulations: The average ratios of exposure to the indicated mAs product (mR/mAs) obtained at any two consecutive tube current settings shall not differ by more than 0.10 times their sum.

$$(X1-X2) \leq 0.10(X1+X2)$$

where X1 and X2 are the average mR/mAs values obtained at each of two consecutive tube current settings. (21 CFR ch 1, 1020.31(c))

- c. Equipment: Electrometer with small ion chamber and timer (or combination unit).
- d. Procedure: Utilize the setup described for reproducibility measurements. Measure and record the exposures at 5 different mA settings while keeping kVp and time constant. With some x-ray units, the mA cannot be varied without varying time. In this instance mA must

be constant and time varied. Divide the mR output by mAs setting, record mR/mAs as calculated.

- e. Interpretation of results: If each of the average ratios between mA stations deviate from the criteria in [Table 2.1](#) consult a qualified service engineer. Linearity of mA/mAs is critical as it directly influences image quality and patient dose.

5. *Kilovoltage Accuracy*

- a. Purpose: To ensure that the x-ray generator is producing the kVp as indicated on the control panel.
- b. Regulations: The accuracy must be $\pm 5\%$ of the nominal control panel setting or within manufacture specifications.
- c. Equipment: kVp meter.
- d. Procedure: Place the kVp meter on the x-ray table top. Set the distance from the focal spot to the table top as indicated in the kVp meter owners manual. Collimate the beam to the active area of the kVp meter. Set the desired starting kVp, mA, and time stations on the generator using the manufacture's suggested techniques. Evaluate kVp settings from 50 kV up to the maximum kV incrementing by 5 kV. During periodic evaluation it may be necessary to evaluate only kVp settings from 60 kV to the maximum kV incrementing by 20 kV unless further measurements are necessary. Make an exposure and record the display value of the kVp meter.

e. Possible Pitfalls:

(1) The HVL should always be measured after assuring the kVp is correct.

(2) The major cause of kVp variation is calibration. Some generators maintain their calibration well and others drift constantly. It is important to note that a change in kVp may not always show as a change in film density because changes in the mA will often compensate for the change in kVp.

(3) Since the kVp affects the radiographic contrast, it must be checked to assure that it is acceptable.

(4) Other major causes of variations in kVp are line voltage drops and electrical component failure.

f. Interpretation of Results: Refer units deviating from the criteria in [Table 2.1](#) for adjustment by a qualified service engineer. Proper kVp calibration is critical as it directly influences image quality and patient dose.

6. Beam Quality

a. Purpose: To assure that the permanently installed filtration at the x-ray tube is maintained at an appropriate level to help minimize patient exposure.

b. Regulations: Federal and many state regulations specify minimum required HVLs at various kVp values. Reference (1), section 1020.30(m) Table 1 is reproduced and can be found at the end of this appendix as [Table B-1](#). For 80 kVp the minimum HVL must be 2.3 mm of aluminum.

c. Equipment: Electrometer with small ion chamber, Five 1 mm Type 1100 Aluminum sheets, Two 0.5 mm Type 1100 Aluminum sheets (if available), BRH test stand (if available).

d. Procedure: Place the ion chamber 5 cm above the table top. Collimate the light field to a narrow beam geometry to include the ion chamber. The aluminum sheets should be placed between the ion chamber and the x-ray tube at a distance $X/2$, where X = focus to detector distance. Make sure the aluminum sheets intercept the entire beam (light field). Make two exposures without any aluminum sheets in the beam. (An exposure made using 80 kVp, 0.10 sec and 320 mA to achieve an output of approximately 300 mR will ensure that you have a high enough exposure to make the measurements accurately and also ensures that your data can be plotted on semi-log paper where the scale is easy to read.) Add aluminum sheets and make additional exposures until the exposure is less than half of the original exposure. Recommend using 2, 3, and 4 mm aluminum. Remove all aluminum sheets and make one exposure. If exposure is not within 2% of the initial exposure, made with 0 mm of aluminum,

repeat the measurement series ensuring that the technique and geometry selected remain the same throughout the procedure.

e. Possible Pitfalls:

(1) The entire ion chamber must be in the x-ray beam. When placing the sheets of aluminum in the beam, be sure that the entire beam is intercepted by the aluminum sheet. Once selected, the technique factors must not be altered for subsequent exposures.

(2) The kVp should be checked before measuring the HVL to ensure that it is within acceptable limits.

(3) The aluminum used for HVL measurements should be type 1100.

(4) For units produced before 1997, in which the HVL is greater than 3.5, further evaluation of the beam quality should be conducted. A service engineer should be consulted to evaluate the cause of the excessive HVL. Units made after 1997 may have dose reduction design characteristics that utilize higher than normal HVL.

f. Interpretation of Results: Plot the exposure values recorded on the semi-log graph paper. The exposure is on the y-axis and the added aluminum thickness is on the x-axis. See [Figure B-1](#) at the end of this appendix for an example. Draw a straight line through the points on the graph. Draw a horizontal line from the point corresponding to one-half of the original exposure to the line drawn through the three exposure points on the graph. Draw a vertical line from that point to the lower horizontal scale and read the HVL (in mm of aluminum) off that scale. If the HVL is not greater than the minimum requirements listed above, consult a qualified service engineer. If the HVL is greater than 3.5 mm of Aluminum, further evaluation should be conducted to determine if the unit contains too much filtration.

7. Output Linearity Tracking by kVp

a. Purpose: To ensure that the output of the x-ray unit is linear as the kVp is increased.

b. Regulations: The average ratios of the exposure to the indicated mAs product

(mR/mAs) obtained at adjacent kVp settings shall not differ by more than 0.10 times their sum.

c. Equipment: Electrometer with small ion chamber.

d. Procedure: Utilize the setup described for reproducibility measurements. Measure and record the exposures obtained using the maximum mAs for each kV setting, incrementing by 10's from 50 kV to 150 kV, during acceptance testing. During periodic evaluation it may be necessary to evaluate a constant mAs at kVp settings from 60 kV to the maximum kV incrementing by 20 kV unless further measurements are necessary. Divide the mR output by mAs setting, record the mR/mAs as calculated..

e. Interpretation of Results: If each of the average ratios between kVp stations deviate from the criteria in [Table 2.1](#) consult a qualified service engineer. Output linearity between kVp stations is critical as it directly influences image quality and patient dose.

8. *Light Field Intensity*

a. Purpose: To ensure that the light field intensity is adequate to illuminate the field.

b. Regulations: The light shall provide an average illumination of not less than 160 lux (15 foot candles) at 100 cm or at the maximum source-image receptor distance (SID), whichever is less. (21CFRch1, 1020.31(d)(2)(ii))

c. Equipment: Light meter capable of providing either lux or foot candles.

d. Procedure: Place the light meter on the x-ray table top. Set the SID to 100 cm or the maximum available whichever is less. Collimate the x-ray beam to a 25 x 30 cm field. Illuminate the field. Measure and record the illumination in the 4 quadrants. Calculate an average.

e. Interpretation of Results: A qualified service engineer should be consulted if the average deviates from the criteria in [Table 2.1](#).

9. *Light Field/X-Ray Beam Alignment*

a. Purpose: To ensure that the x-ray field and the light field are congruent

b. Regulations: The light field/x-ray field alignment should be within $\pm 2\%$ of the SID. (21CFRch1, 1020.31(d)(2)).

c. Equipment: Five coins or a x-ray beam alignment test tool (if available) and the collimator alignment template, film, and a ruler.

d. Procedure: Place a cardboard cassette or ready pack film on the x-ray table top. Center the light field on the film holder at a 40 inch SID. Tape the film holder to the table. Position the collimator alignment template so that it is centered in the light field and manually collimate the light field to the alignment marks on the template (or to 7x8 inch field size if the five coins are used). Place the x-ray beam alignment test tool in the exact center of the template. (If a test tool is not available place the edge of a coin on the each margin of the light field such that the edge of the coin is inside the light field. Place the fifth coin in the quadrant of the light field toward you and to the right as an orientation marker. Mark the center of the light field by laying a pen with the tip pointing at the light field center crosshair or use a radio-opaque B-B marker.) Make an exposure using 80 kVp, 32 mAs for ready pack film or 80 kVp and 20 mAs for a cardboard cassette. Place a loaded cassette in the bucky tray. Allow the PBL system to automatically collimate to the cassette size. (if available) Make a second exposure at 80 and < 1 mAs kVp,. Develop the films. From the film exposed on the table top, measure the deviation between the X-ray field and the edge of the light field (defined by the inscribed light field alignment marks on the test tool or the edges of the four coins).

e. Interpretation of Results: Consult a qualified service engineer if the alignment deviates from the criteria in [Table 2.1](#).

9a. *X-ray Field Size- Indicated vs. Actual*

a. Purpose: To ensure that the actual and indicated X-ray field are congruent.

b. Regulations: The indicated vs. actual x-ray field should be within $\pm 2\%$ of the SID. (10 CFR 1020.31(e)(3))

c. Equipment: Bucky film developed from previous procedure and a ruler.

d. Procedure: Utilizing the bucky film developed in the previous procedure measure the size of the X-ray field.

e. Interpretation of Results: Consult a qualified service engineer if the alignment deviates from the criteria in [Table 2.1](#).

10. *Central Beam Alignment*

a. Purpose: To ensure that the central x-ray beam is perpendicular to the table.

b. Regulations: The perpendicularity of the central beam should be within 5mm.

c. Equipment: Table top film from procedure 9.

d. Procedure: If the x-ray beam alignment tool was used, measure the deviation between the upper (magnified) bead and the lower bead. If the five coins and marker were used, draw a line connecting the opposite corners of the x-ray field and measure the deviation between the location the lines cross and the marker.

e. Interpretation of Results: Consult a qualified service engineer if the perpendicularity measured deviates from the criteria in [Table 2.1](#).

11. *Indicated SID*

a. Purpose: To ensure the actual source to image distance (SID) and the indicated SID are congruent.

b. Regulations: The actual SID should be within $\pm 2\%$ of the indicated SID.

c. Equipment: Tape measure.

d. Procedure: Position the tube assembly at 40 inches from the image receptor. Measure the SID. If a automatic detent is available, position the assembly utilizing the detent. Measure the SID.

e. Interpretation of Results: Consult a qualified service engineer if the measurement deviates from the criteria in [Table 2.1](#).

12. *Positive Beam Limiting System*

a. Purpose: To ensure that systems providing a beam limiting device function properly. Units manufactured after 3 May 1993 are not required to be equipped with a beam limiting device.

b. Regulations: Either the length or width of the x-ray field in the plane of the image receptor differs from the corresponding image receptor dimension by more than 3 % of the SID. (10 CFR 1020.31(g)(1)(i). The x-ray beam axis is perpendicular to the plane of the image receptor to within ± 3 degrees. (10 CFR 1020.31(g)(2)(iv).

c. Equipment: Table top and bucky films developed in procedure 9. Cassettes of various sized used clinically and scrap piece of film for each size cassette being tested.

d. Procedure:

(1) Place both the table top and the bucky tray film in the same orientation side by side on a viewbox. Determine the maximum area of the bucky tray film by observing the outermost image of the measuring scale (or coin edges) seen on the alignment template along all four dimensions of the film. Mark the corresponding numeric information onto the scale imaged on the table top film. Measure the difference between the area image on the bucky tray and table top films to determine the total misalignment. Measure the perpendicularity of the central beam as described in procedure 10.

(2) Set the x-ray tube at the SID commonly used. Make sure the PBL selector is set to automatic mode. Insert a cassette and ensure that the cassette is centered with the bucky tray centering light. Push the tray in and check visually that the changes in the light field size correspond with cassette size. Compare the light field with a scrap film of the same cassette size (in tray) by placing on the table top and measuring the differences using a ruler and record.

e. Interpretation of Results: The magnification factor should be factored in when calculating the size of the light field on the table top with respect to the size it should be in the bucky. Consult a qualified service engineer if the alignment deviates from the criteria in [Table](#)

2.1.

13a. **Focal Spot Size**

(For focal spots less than 1.0 mm in size)

a. **Purpose:** To ensure that the focal spot size is within acceptable limits.

b. **Regulations:** National standards allow the measured size to be 1.5 x nominal perpendicular to the anode-cathode axis and 2.15 x nominal parallel to the anode-cathode axis. The nominal or stated size can usually be found in the technical manual or back of the tube head.

c. **Equipment:** 2 degree star pattern for focal spot sizes of 0.6 mm or greater, a 0.5 or small degree star pattern for smaller focal spot sizes, ready pack film. (A slit or pinhole camera may be used, the procedure will not be discussed in this section.)

d. **Procedure:** Choose the appropriate star pattern. Place the ready pack film or loaded cardboard cassette on the x-ray table top and tape it to the table top. Tape the star test pattern to the collimator face plate so that the radiographic central ray is perpendicular to the star pattern. (The star pattern may also be placed on a stand.) The central ray should pass through the center of the star pattern. The spokes of the pattern should lie along the tube axis. Place a radio-opaque marker on the table top to designate the anode/cathode axis. Set the focal spot-to-film distance (FFD) to twice the focal spot-to-test pattern distance (FTD) and collimate the beam so that the total test pattern is included in the field. (The FTD will be about 12" if you tape the test pattern to the collimator face plate.) You should have a magnification factor (M) of 2 (FFD/FTD). Expose the film using approximately 80 kVp and 32mAs for ready pack film or 80 kVp and 20 mAs for a cardboard cassette. Develop the film.

e. **Interpretation of Results:** Measure the total diameter of the star pattern image on the radiograph. This dimension should be about 90 mm ± 2 mm, assuming a 45 mm star target. Divide the diameter measured on the radiograph by the true diameter. The magnification factor, $M = \text{FFD}/\text{FTD}$, should be about 2. Starting at the outside edges of the star test pattern and the same direction as the anode-cathode axis, move toward the center of the image and mark on both sides where the bars first disappear. Repeat the

procedure in the other direction, i.e., 90 degrees to the anode-cathode axis. With small focal spots, you should count the number of imaged spokes to ensure first blur is visible. With a clear plastic ruler measure the distance between the marks and record these dimensions with respect to the anode-cathode axis. Repeat for 90 degree axis. Compute the focal spot size using the following equation:

$$F = \frac{NxD}{57.3(M-1)}$$

F: focal spot size in mm

N: degrees in star pattern

D: diameter of zero contrast region in mm

M: magnification

The width is determined by the measured dimension along the anode-cathode axis and the length is computed from the dimension measured at 90 degrees to the anode-cathode axis.

Focal spot size can indicate the physical condition of the anode. If the anode is pitted due to age or abuse the focal spot size will increase compared to the values obtained from previous x-ray surveys. Thus, the results can help determine if the unit or insert is due for replacement.

13b. **Focal Spot Constancy**

(alternative method for periodic evaluation)

a. **Purpose:** To ensure that the spatial resolution of the x-ray system is remaining constant.

b. **Regulations:** During periodic evaluations the spatial resolution should not change significantly over time.

c. **Equipment:** Right cylinder power target test tool, ready pack film /cardboard cassette.

d. **Procedure:** Utilize the setup described for the focal spot size measurement. The magnification factor should be greater than 2. Two exposures are required, one with the bar pattern oriented parallel to the anode-cathode axis and one with it oriented perpendicular.

e. Interpretation of Results: The high-contrast resolution pattern images should be viewed under masked conditions with a 10x to 30x magnification. If the resolution has significantly changed since the last further evaluation of the focal spot size should be conducted to determine if the unit or insert is due for replacement.

14. *Automatic Exposure Control (AEC) System* (if applicable)

a. Purpose: To ensure that the automatic exposure control system is responding adequately. The system compensates for variations in technique factors and patient thickness such that resulting films appear with constant, optimal densities. This evaluation assumes proper operation of the processor used to develop films. It also assumes that the AEC system is calibrated for the film/screen combination used with the unit. Therefore, the processor, cassette, and film used for testing should be those actually used during patient imaging. Also, test films should all come from the same emulsion batch. The following AEC parameters should be evaluated during testing: reproducibility, balance, maximum exposure time, kVp compensation, thickness compensation and density control tracking.

b. Regulations: For each ion chamber measurement the reproducibility should be within $\pm 5\%$. In comparing each ion chamber, all measurements should be within ± 0.1 OD of each other. Back up timer should terminate the exposure at 600 mAs or 2000 mAs for tube potentials less than 50 kVp. Film optical densities should be less than ± 0.3 for thickness compensation and kVp compensation. Density control function should vary approximately 25% between settings.

c. Equipment: 4 cm Al or 18 cm acrylic phantom, 1.6 mm Pb plate, 14" x 17" (35 cm x 43 cm) loaded cassette, electrometer with small ion chamber.

d. Procedure: For a radiographic system, set the x-ray tube at 40 inches (72 inches for chest systems) target film distance and center to the cassette. Set selector such that only one phototimer is activated. To determine the location of the phototimer(s) look at the chest unit pattern of rectangles on the chest board surface. Use the same layout for the table, noting that the center chamber is usually located

at the lateral center of the table when the tube and bucky are aligned. Record the SID, film/screen combination and film size used for future testing reproducibility. Place a loaded cassette in the bucky tray. Place a 4 cm aluminum or 15 cm acrylic phantom in the beam. Ensure that the phantom covers all the AEC detector cells. Best results occur if the attenuator is placed on the table or at the chest board surface. If doubt exist for the location of the chamber, place the attenuator at the collimator. Set the control in the photo-timing mode, 80 kVp and select the detector to be checked (e.g. table, center chamber). A single cassette should be used for all testing, to reduce variability. This will require processing the film after each exposure.

(1) Optical Density (OD): Make an exposure using the setup described. Develop the film. Measure and record the OD at the center of the field. The OD should be at least 1.2. The radiologist may set a higher baseline density. The range of densities should be within ± 0.15 of the baseline density. If the OD does not fall within this range further evaluation is required to determine if the x-ray system requires adjustment or if the processor is not functioning properly.

(2) Output Reproducibility: Use the setup previously described. Place the ion chamber along the beam central axis at the phantom beam entrance surface. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Substitute an exposed piece of film for fresh film during this test. Irradiate the phantom, ion chamber and cassette holding exposed film three times. Record the exposure readings and calculate their mean. All three readings should line within $\pm 5\%$ of their mean. Repeat for each detector.

(3) Back-up Timer: Use the setup previously described. Place the lead sheet over the AEC detector fields so that no radiation reached them. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Retain the previously exposed film from the reproducibility test. Irradiate the phantom until the AEC shuts off the beam. Record the elapsed mAs. The beam should terminate prior to the accumulation of 600 mAs or 2000 mAs for tube potentials less than 50 kVp.

(4) Phototimer Balance: Use the setup previously described. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Irradiate a separate piece of film for each detector. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.1 of the baseline density.

(5) Patient Thickness Compensation: Use the setup described previously. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Vary the phantom thickness over the range: 2, 4 cm Al or 12, 15, 18 cm acrylic, irradiating a separate film for each phantom thickness. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.3 of the baseline density.

(6) kVp Compensation: Use the setup previously described. Place a fresh piece of film in a cassette and load the bucky tray. Set the technique at 80 kVp, 200 mA, AEC setting to neutral (0). Vary the kVp over the clinically used range 70, 90, 110, irradiating a separate film for each voltage applied. Record the elapsed mAs for each image and measure OD at the center of each processed film using a densitometer. The densities should lie within the range of ± 0.3 of the baseline density.

(7) Density Control Tracking: Use the setup previously described. Place the ion chamber just off the beam central axis at the phantom beam entrance surface. Set the technique at 80 kVp and 200 mA. Vary AEC density over the range of available positive and negative settings, exposing a new piece of film for each setting. Record the elapsed mAs, density at the center of each film, and exposure for each image. The density function should operate as expected, + gives exposure and density increase, - gives exposure and density decrease. The exposure difference per step should meet the manufacturer's specifications or in the absence of such data, be balanced about the neutral setting output at 25% per step.

e. Interpretation of Results: Units deviating from the criteria in [Table 2.1](#) should be

referred for adjustment by a qualified service engineer.

15. *Entrance Skin Exposure Measurements (ESE)*

See [chapter 15](#) and [appendix I](#).

B. Survey Procedures for Portable and Mobile Radiographic Equipment

The following modifications of quality control procedures and acceptance parameters from fixed x-ray units apply for portable and mobile units:

1. Visual Inspection

a. The minimum source to skin distance must be no less than 12 inches (30 cm). This can be measured directly with a tape measure provided the location of the focal spot is known.

b. The operator must be able to stand at least six feet away from the x-ray tube during the actual exposure. This is normally accomplished by attaching the exposure switch to the unit with at least a six foot long cord.

c. Each portable unit should be supplied with at least two lead aprons and gonadal shields for use with children and patients under the age of 45.

2. Generator checks

a. Conventional portable generators

Pay special attention to short exposure times such as those used in chest radiography. On single mA station equipment, perform reproducibility studies at a short (1/60 - 1/30 sec), medium (1/2 sec) and long (> 1 sec) exposure time. Although not a true linearity, compare the mR/mAs for 3 or 4 time stations.

b. Battery powered generators

Perform a battery depletion study. Completely charge the storage batteries. Select an average technique for the day-to-day work load. Using a dosimeter, measure the output for three exposures at the preselected technique. If the machine has power assisted motion, drive the unit the typical distance one would travel between patient rooms. Repeat the three exposures and movement sequence until the output falls to 80% of its initial level. Plot output versus the number of exposures. If the typical number of exposures per portable run falls short of the number required to reduce output to the 80% level, operators should have little trouble producing consistent density images

if all other radiographic factors are properly controlled.

c. Capacitor discharge generators

The kVp measurement on capacitor discharge equipment will need special acceptance limits. A typical capacitor discharge unit (1 microfarad capacitor) will lose 1 kVp for each mAs of exposure. For example, a typical kVp test cassette exposure for 80 kVp will require 20 mAs, and will yield a final minimum of 60 kVp with an average kVp of about 70. Also, the filtration used in the test cassette preferentially attenuates lower energy photons, which will yield a kVp reading higher than the average kVp.

3. Performance Limits

a. Conventional and battery-powered portable units should meet the performance limits outlined for fixed equipment. Capacitor discharge equipment should meet all fixed system performance limits except for measured kVp. The kVp should be measured with a non-invasive device after the system has been calibrated by a service engineer. The quality control test result (at a specific mAs), rather than the indicated kVp, becomes the operating level.

b. All of the appropriate output quantities should be evaluated any time major maintenance is performed, especially battery service.